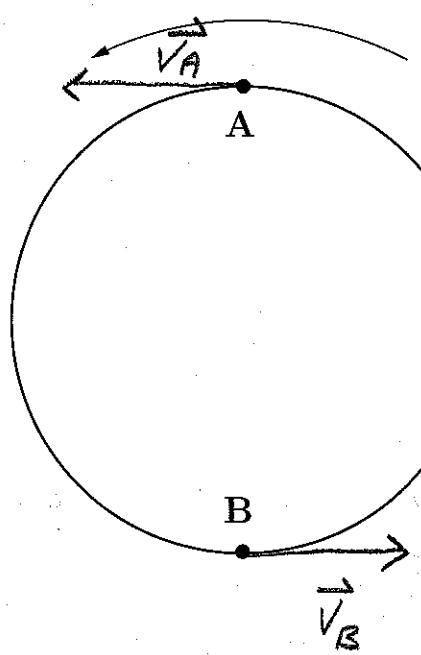
PHYS 211E— Exam #1
Thursday, September 25, 2008

Name:____________________________________

1. A particle with mass $m = 2\,\mathrm{kg}$ travels *counterclockwise* around a circle with a constant speed of $v = 6\,\mathrm{m/s}$. The radius of the circle is $R = 2/\pi = 0.955\,\mathrm{m}$. At time $t_1 = 0\,\mathrm{s}$ the mass is at position **A** at the top of the circle, and at time $t_2 = 0.5\,\mathrm{s}$ the mass is at position **B** at the bottom of the circle.

   Calculate the *average* acceleration $\overline{\vec{a}}$ over the time interval from t_1 to t_2.



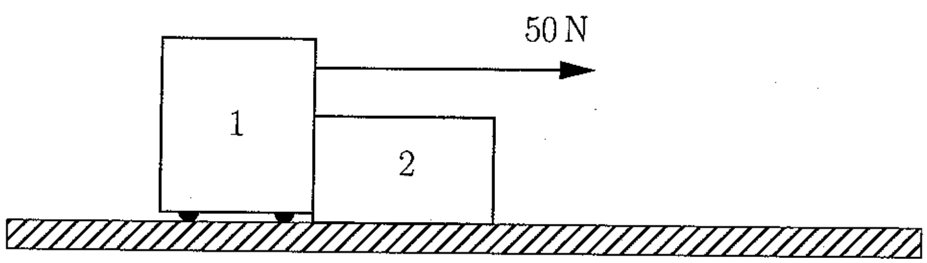
$$\overline{\vec{a}} = \frac{\Delta \vec{V}}{\Delta t} = \frac{\vec{V}_B - \vec{V}_A}{\Delta t} = \frac{(6\,m/s\,\hat{i}) - (-6\,m/s\,\hat{i})}{0.5\,s}$$

$$= \frac{12\,m/s\,\hat{i}}{0.5\,s}$$

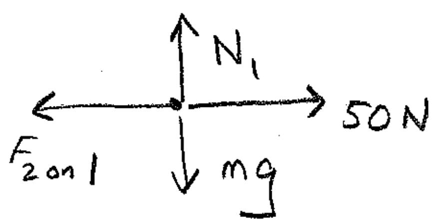
$$= 24\hat{i}\,m/s^2$$

2. Consider the two illustrated blocks being pulled to the right by a string attached to block 1. The string exerts a force of 50 N on block 1; it is not attached directly to block 2. The blocks both have the same mass $m = 20\,\text{kg}$, but they do not experience the same frictional forces. Block 1 has tiny frictionless wheels (like the carts you used in lab) and can be considered to slide over the table with no friction at all. Block 2 slides along the table with a coefficient of sliding friction $\mu_k = 0.2$.

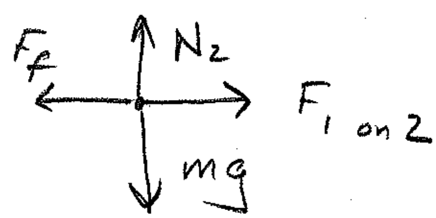
Calculate the (vector) force exerted by block 2 on block 1.



(1)



(2)



Block 1:

$\vec{F}_{net} = m\vec{a}$

$F_{net,x} = ma_x$ $\quad$ $F_{net,y} = 0$

$50 - F_{2\,on\,1} = ma$

Block 2:

$\vec{F}_{net} = m\vec{a}$ $\quad$ $N_2 - mg = 0$

$F_{1\,on\,2} - F_f = ma$ $\quad$ $N_2 = mg$

$F_{1\,on\,2} - \mu mg = ma$

Combine, and recognize $F_{1\,on\,2} = F_{2\,on\,1} = F_{contact}$

$50 - F_{contact} = F_{contact} - \mu mg$

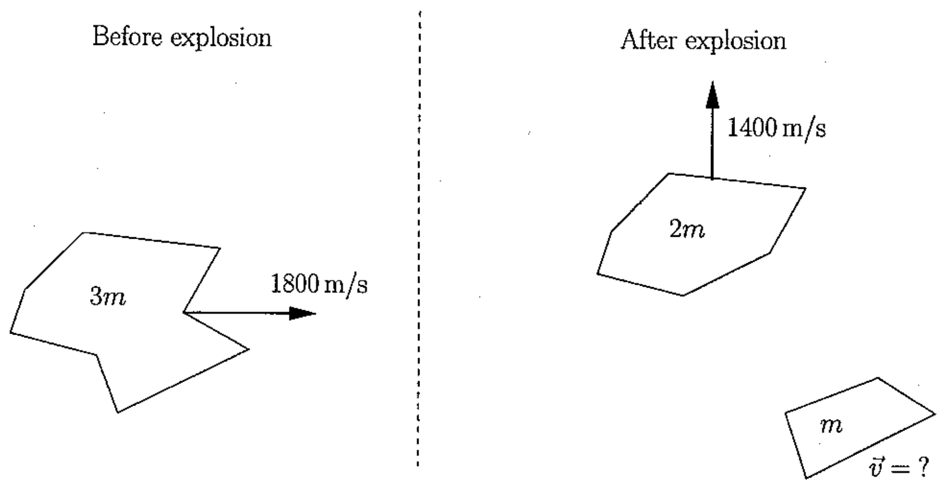
$2F_{contact} = 50 + \mu mg$

$F_{contact} = 25 + \frac{1}{2} \times 0.2 \times 20 \times 9.8 = 44.6\,\text{N}$

$F_{2\,on\,1}$ acts to the left.

3. An asteroid with mass $3m$ heads directly toward the earth at a speed of 1800 m/s. Fortunately, a crack team of physicists and aeronautical engineers send a robot to the asteroid to attach carefully placed explosives. The explosives are detonated and the asteroid breaks into two pieces with masses m and $2m$. The large mass moves in a direction perpendicular to the original velocity of the asteroid with a speed of 1400 m/s as illustrated. (The mass of the robot and the explosives can be considered to be negligible compared to the mass of the original asteroid and the fragments.)

Determine the speed and direction of the motion of the smaller mass after the explosion.



$\vec{P}_{before} = \vec{P}_{after}$

P_x before = P_x after

$3\cancel{m} \times 1800 = 2m \times 0 + \cancel{m} V_x$

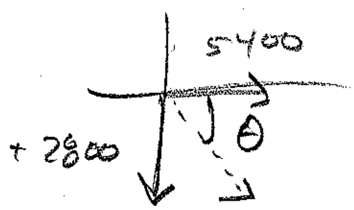
$\Rightarrow V_x = 5400$ m/s

P_y before = P_y after

$0 = 2\cancel{m} \times 1400 + \cancel{m} V_y$

$\Rightarrow V_y = -2800$ m/s

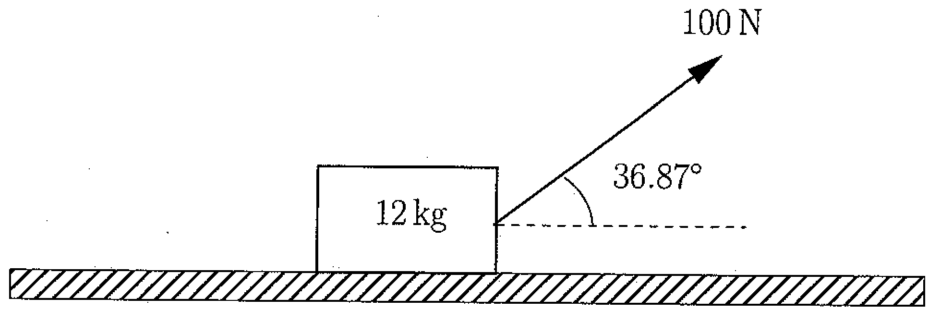
$V = \sqrt{V_x^2 + V_y^2} = 6083$ m/s



$\theta = \tan^{-1} \frac{2800}{5400} = 27.4^{\circ}$ below positive x-axis.

4. A block with mass $m = 12\,\text{kg}$ is pulled along a rough floor by a rope that is inclined above the horizontal by 36.87°. The rope exerts a constant force of 100 N on the block. The block starts from rest, and after it is pulled a distance of 3 m it is moving at a speed of 5 m/s.

Calculate the work done by friction during this process.



$$\Delta K = W_{net}$$

$$(K_f - K_i) = W_{rope} + W_{fric}$$

$$\left(\tfrac{1}{2} m v_f^2 - 0\right) = T \times 3m \times \cos 36.87° + W_{fric}$$

$$W_{fric} = \tfrac{1}{2} m v_f^2 - T \times 3 \times \cos 36.87°$$

$$= \tfrac{1}{2} \times 12 \times 25 - 100 \times 3 \times 0.8$$

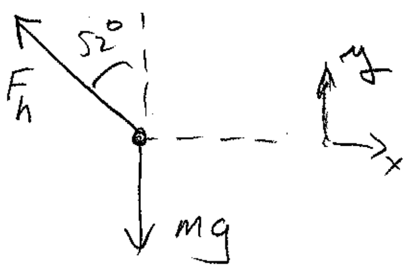
$$= 150 - 240$$

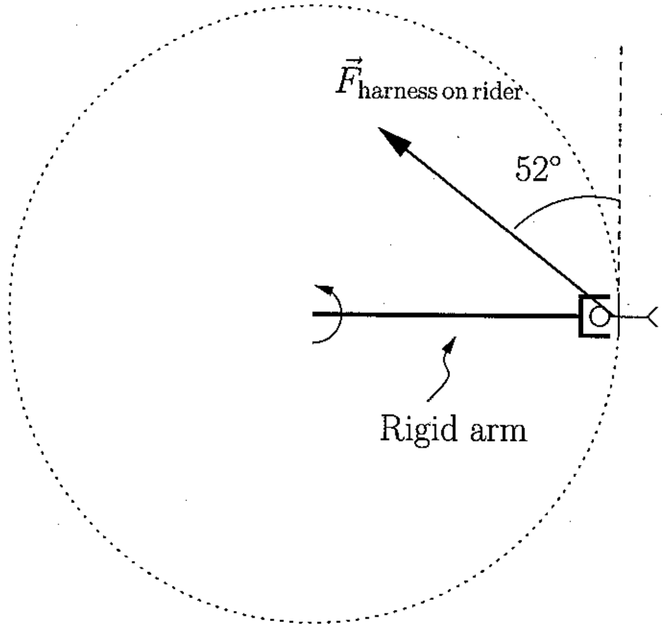
$$= -90\,\text{J}$$

5. The new "Spin & Spew" ride at Hershey Park consists of a harness attached to rigid arm. The rider is spun counterclockwise at a constant speed in a vertical circle of radius 11 m. When a 62 kg rider is at the illustrated position the total force of the harness on the passenger is in a direction 52° from vertical as illustrated. (NOTE: The arm is rigid, so it's not like a rope; it can exert a force with a component perpendicular to the arm itself.)

Determine the speed and acceleration of the rider at this position.

Force Diagram on Rider





$$\vec{F}_{net} = m\vec{a}$$

$$F_{net,x} = ma_x \qquad F_{net,y} = ma_y$$

$$-F_h \sin 52^\circ = -\frac{mv^2}{r} \qquad F_h \cos 52^\circ - mg = 0$$

$$\Rightarrow v^2 = \frac{rF_h \sin 52^\circ}{m} \qquad \Rightarrow F_h = \frac{mg}{\cos 52^\circ}$$

$$= \frac{r\,mg \sin 52^\circ}{m \cos 52^\circ}$$

$$= gr\tan 52^\circ \longrightarrow v = \sqrt{gr\tan 52^\circ} = \sqrt{9.8 \times 11 \times \tan 52^\circ}$$

$$= 11.75 \text{ m/s}$$

$$a = \frac{v^2}{r} = \frac{11.75^2}{11} = 12.5 \text{ m/s}^2 \text{ directed to left}$$

6. A block slides down a frictionless inclined plane as illustrated. A taut cord puts a force on the block directed *up* the plane. How do the block's total mechanical energy E and potential energy U change as the block slides down the plane? (Circle one)

(a) E decreases, U decreases

(b) E decreases, U increases

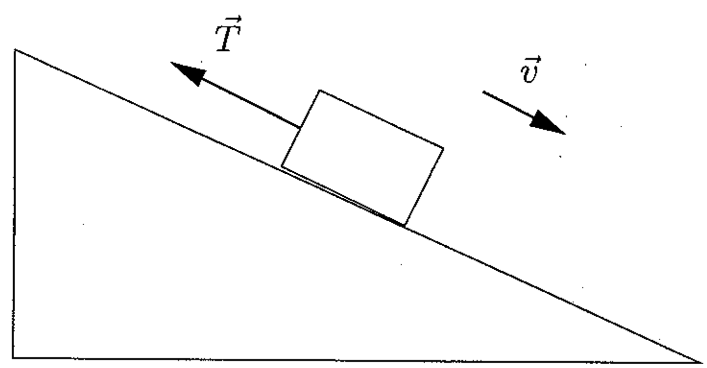
(c) E stays the same, U decreases

(d) E stays the same, U increases

(e) E increases, U decreases

(f) E increases, U increases

(g) Not enough information given to answer the question



$\Delta K + \Delta U = W_{n.c.}$

or $\Delta E_{mech} = W_{n.c.}$

$W_{n.c.} < 0$ because $\vec{T}$ and $\Delta\vec{r}$ point in opposite directions. ($\theta = 180°$).

$\Rightarrow \Delta E_{mech} < 0$.

$\Delta U = mg\Delta h$; $\Delta h < 0 \Rightarrow \Delta U < 0$